Morphology study of Gold electrolytic-thin-films for applications in MCM-D

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1. Abstract

The vertiginous scaling evidenced by the microelectronic industry in the last 30 years has been the mainstream in the development of high-performance integrated circuits. Among these trends, Multi-Chip Module (MCM) integration technology stands out as a solution to such requirements. MCM technology is a special packaging process where several integrated circuits are packaged as a single component. In this technology, ensuring a high-quality interconnection constitutes an essential condition for the proper functioning of the module. The present work reports the morphological study made in electrolytic gold (Au) thin-films for applications as conducting layers in MCM devices. The study evidenced that the use of TiW or NiCr as barrier materials does not have a significantly influence in the morphological properties of the electrolytic Au thin films deposited.

2. Introduction

In recent decades, the continued development of microelectronics added to the emergence of new systems architectures and increasing demand for portable systems, has resulted in the need for electronic devices with high integration, small size, low power consumption and high performance. In this context, Multi-Chip Module (MCM) integration technology offers new challenges and opportunities by combining multiple integrated circuits into one functional unit. That is, the various chips and components are positioned and interconnected on a same substrate by wire bonding, Tape Automated Bonding (TAB) or Flip-Chip [1, 2]. Among the several advantages that this technology suggests we can mention: allows better performance by having shorter interconnections, less inductance and parasitic capacitance and less crosstalk; encourages the miniaturization of the module compared to other integration methods and enables a wide range of applications (e.g. in communications systems and especially radio-frequency circuits) due to its compatibility with technologies such as Si, GaAs, etc. According to the type of substrate as well as the production technology used, MCMs are divided into three groups: those using laminated (MCM-L), those using ceramic (MCM-C) and those using deposited thin film (MCM- D) [1, 2]. In the technological process of MCM-D production proposed by our research group (Electronic Packaging Research Group, Renate Archer Center for Information Technology (NEE-CTI)) it will be used alumina (Al_2O_3) as substrate and polymer benzocyclobutene (BCB) photosensitive as an insulator and a dielectric in the capacitive elements of the MCM-D device. The interconnections and the passive elements will be formed by several sequences of deposited metallic thin films and defined by photolithography processes, where tantalum nitride (TaN) will be used as resistive layer, nickel-chromium and/or titanium-tungsten (NiCr and/or TiW) as the barrier layer and gold (Au) as the conducting layer [3]. A schematic of the final device is shown in Fig 1.

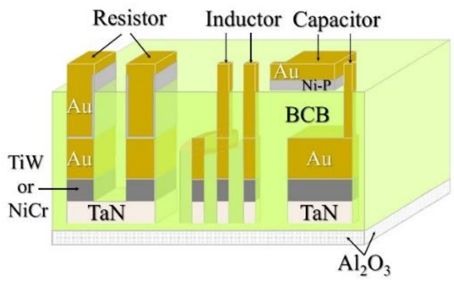

Fig.1. *Schematic of the MCM-D.*

So, Au thin films are responsible for these interconnections. Therefore, a good control of the parameters involved in the deposition process of these films, as well as their properties, is decisive in the standardization of the MCM-D manufacturing steps. The present work shows the morphological studies made in Au thin films obtained by electrolytic deposition over two different metals sequence: Au over titanium tungsten (TiW)/tantalum nitride (TaN) and Au over nickel-chromium (NiCr)/tantalum nitride (TaN), in order to evaluate the influence of these materials in the quality of the films. Samples were analyzed by means for Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and X-ray Dispersion Spectrometry (EDS). Only alumina substrates were used, so the influence of the substrate on the morphological properties of the films is not evaluated at this moment.

3. Experimental Details

The samples investigated in this work were carried out onto Al_2O_3 wafers (99.9 % and 2.5×2.5 cm) covered by a 5 μm-polymer-film of benzocyclobutene (BCB) photosensitive (Cyclotene 4024-40, Dow Company) that act as electrical insulation and smooths the Al_2O_3 surface in order to improve the adhesion of the following films. Then, metallization was performed. Thin films of TaN (100 nm), TiW (30 nm) and/or NiCr (30 nm) and Au (100 nm) were deposited by reactive DC sputtering (Sputron II-Balzer) at 1.0 kV. To finish, the Au films were thickened by an electrolytic commercial solution (Auruna 553-Umicore) up to 1 μm, where the electrolytic depositions were carried out at 60 °C (± 2°C) during an hour (60 min) and using a current density of 0.1 A/dm^2. Once the samples were obtained measurements of AFM using a Nanosurf, FlexScan, and SEM and EDS using a FIB/SEM system Dual Beam model Nova 200 Nanolab were performed. The AFM images were analyzed using the software WSxM 5.0 Developed 3.3 [4].

4. Results and Discussion

Fig. 2 shows the SEM images (left) and the EDS spectra (right) from the Au films thickened by electrodeposition, and from the Au film grown by sputtering. From this figure it can be seen that, for the experimental deposition conditions used, thickening of the Au films occurred, without significant incorporation of impurities as evidenced by the EDS spectra. This Fig also shows that, although Au films were deposited on different barrier layers (TiW and NiCr), they showed no significant differences in roughness or morphology.

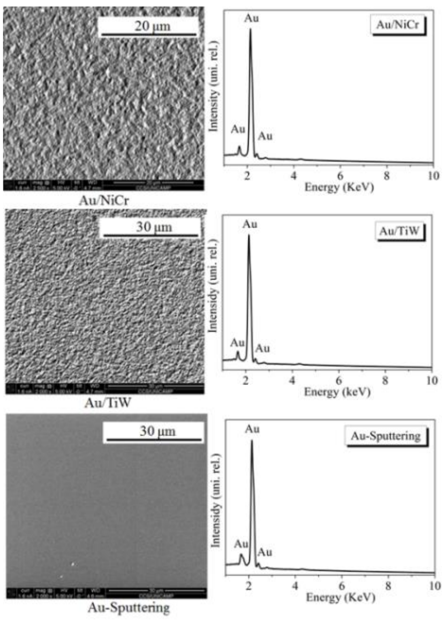

Fig.2. *SEM images (left) and EDS spectra (right) from the electrolytic Au thin films and from the Au grown by sputtering.*

These results are corroborated by the AFM measurements. Fig. 3 shows AFM images (top) and superficial topographic analyzes (bottom) from the electrolytic Au thin films deposited over TiW and NiCr. In here, a roughness variation in a few nanometers (1.9 nm) and a very similar surface topography and films thickness can be observed.

Although in the samples studied, the use of TiW and NiCr as barrier materials does not significantly influence the morphological characteristics of the films; the roughness can still be reduced for a better MCM-D application. Thus, a fine tuning of the electrolytic deposition conditions (e. g. in parameters such as current density and deposition time) will be performed as next steps to ensure the production of more homogeneous lower roughness films.

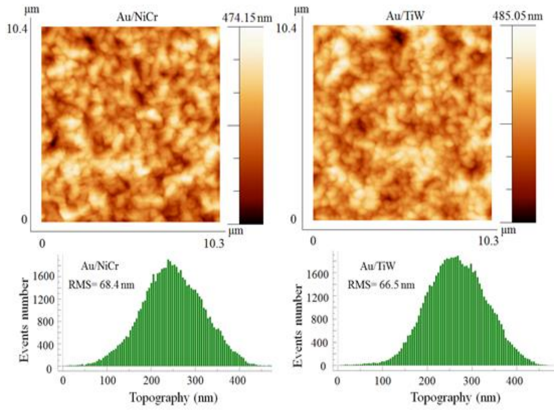

Fig.3. *AFM images (top) and superficial topographic analyzes (bottom) from the electrolytic Au thin films.*

5. Conclusions

In this study, it is evidenced that the use of TiW or NiCr as barrier materials does not have a significantly influence in the morphological properties of the electrolytic Au thin films deposited. However, the thicknesses and roughness observed in these films can still be improved for MCM applications as conductive layer. New experimental tests will be done to ensure the production of electrolytic Au films highly dense and with a good control of the thickness.

Acknowledgments

The authors would like to acknowledge Alfredo Rodrigues Vaz from CCSNano/Unicamp for SEM and EDS measurements and LNNano/CNPEM for the support on samples fabrication.

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